

SECTION 03 37 13

SHOTCRETE

PART 1 – GENERAL

1.01 SECTION INCLUDES

- A. Preparation of substrate surfaces.
- B. Shotcrete placement.
- C. Curing.

1.02 RELATED SECTIONS

- A. Reinforcing steel as specified in Section 03 20 00, Concrete Reinforcing.
- B. Formwork as specified in Section 03 11 00, Concrete Forming.
- C. Construction joints as specified in Section 03 30 00, Cast-In-Place Concrete.

1.03 MEASUREMENT AND PAYMENT

- A. General: Measurement and payment for shotcrete will be either by the lump-sum method or by the unit-price method as determined by the listing of the bid item for shotcrete indicated in the Bid Schedule of the Bid Form.
- B. Lump Sum: If the Bid Schedule indicates a lump-sum for shotcrete, the lump-sum method of measurement and payment will be in accordance with Section 01 20 00, Price and Payment Procedures, Article 1.03.
- C. Unit Price: If the Bid Schedule indicates a unit price for shotcrete, the unit-price method of measurement and payment will be as follows:
 - 1. Measurement:
 - a. Shotcrete will be measured for payment by the cubic yard of each mix placed in the work. The quantity for payment will be the actual or indicated square area placed multiplied by the thickness indicated on the Contract Drawings, unless a different thickness is approved by the Engineer.
 - b. Reinforcing steel will be measured for payment by the pound as specified in Section 03 20 00, Concrete Reinforcing.
 - c. Rebound will not be measured or included for payment.
 - 2. Payment: shotcrete will be paid for at the indicated Contract unit prices for the computed quantities as determined by the measurement method specified in Article 1.03.C.1.

1.04 REFERENCES

- A. American Concrete Institute (ACI):
 - 1. ACI 506.2 Specifications for Shotcrete
- B. American Society for Testing and Materials (ASTM):
 - 1. ASTM C31/
C31M Standard Practice for Making and Curing Concrete Test Specimens in the Field
 - 2. ASTM C33/
C33M Standard Specification for Concrete Aggregates
 - 3. ASTM C42/
C42M Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
 - 4. ASTM C94/
C94M Standard Specification for Ready-Mixed Concrete
 - 5. ASTM C150/
C150M Standard Specification for Portland Cement
 - 6. ASTM C494/
C494M Standard Specification for Chemical Admixtures for Concrete
 - 7. ASTM C1604/
C1604M Standard Test Method for Obtaining and Testing Drilled Cores of Shotcrete
 - 8. ASTM E329 Specification for Agencies Engaged in Construction Inspection, Testing, or Special Inspection

1.05 DEFINITIONS

- A. "Shotcrete" is defined as pneumatically placed concrete: A portland-cement concrete mixture conveyed through a hose and nozzle, and shot onto a surface at high speed by means of air pressure.

1.06 SUBMITTALS

- A. Refer to Section 01 33 00, Submittal Procedures, and Section 01 33 23, Shop Drawings, Product Data, and Samples, for submittal requirements and procedures.
- B. Submittals shall include the following requirements:
 - 1. Mix design;
 - 2. Methods of application and equipment;
 - 3. Certificates of compliance for materials;

4. Test results; and
5. Sample test panels.

1.07 QUALITY ASSURANCE

- A. Shotcrete work shall be performed by a firm or company regularly engaged in the business of applying shotcrete materials, using nozzle operators and workers skilled and experienced in the type of work specified.
- B. Shotcrete supervisor shall have not less than two years' experience as a shotcrete nozzle operator.
- C. Nozzle operator shall have not less than one year experience and, upon request of the Engineer, shall demonstrate ability to properly place shotcrete.

1.08 ENVIRONMENTAL CONDITIONS

- A. Shotcrete shall not be placed during inclement or windy weather.
- B. Proper protective clothing shall be worn by operators, and any person in the area shall wear a mask during shotcreting until operations are stopped and the dust has cleared.

1.09 PROTECTION:

- A. Protect adjacent surfaces from overspray and damage due to shotcreting operations. Prevent dust nuisance.

PART 2 – PRODUCTS

2.01 MATERIALS

- A. Portland Cement: ASTM C150/C150M, Type II. Type III cement may be used, subject to written approval of the Engineer.
- B. Aggregate: ASTM C33/C33M normal weight aggregate with combined gradation of coarse and fine aggregates conforming to ACI 506.2, Gradation No. 1 or Gradation No. 2, as applicable to the work.
 1. Maximum aggregate size may be varied, subject to acceptance by the Engineer.
 2. Specific gravity of aggregate shall be not less than 2.50.
- C. Water: Clean and potable, free of impurities detrimental to shotcrete.
- D. Admixture: ASTM C494/C494M, Type C or Type E, containing no water-soluble chlorides or materials corrosive to steel or other properties that may cause cracking or spalling (for wet-mix shotcrete only.)

- E. Ground Wires: No. 18 or 20 gage steel annealed wire.
- F. Thickness Pins: Noncorrosive thickness-indication pins designed not to cause infiltration of water through shotcrete.
- G. Reinforcing Steel: Comply with applicable requirements of Section 03 20 00, Concrete Reinforcing.

2.02 MIX DESIGN

- A. Design of shotcrete mix, whether dry-mix shotcrete or wet-mix shotcrete, including recommended amounts of admixture and water to be used, shall be obtained by the Contractor from a qualified independent testing laboratory or agency, or from a mill or ready-mix plant, properly equipped to design shotcrete/concrete mixes. The laboratory, agency, mill or ready-mix plant shall meet the applicable requirements of ASTM E329, and shall meet with approval of the Engineer. The mix design shall be certified and signed by a professional engineer who is currently registered as a civil or structural engineer in the State of California. Costs of obtaining the mix design shall be paid for by the Contractor.
- B. Shotcrete mix shall conform with the following requirements:
 - 1. Proportion of cement to aggregate shall be as required to achieve the indicated or specified strength.
 - 2. Water content at time of discharge from nozzle shall not exceed amount required to achieve the maximum permitted slump.
 - 3. Compressive strength of shotcrete shall be not less than the indicated or specified 28-day compressive strength (pounds per square inch).
- C. Upon receipt of acceptable shotcrete mix design and test results from the pre-approved independent testing laboratory, agency, mill, or ready-mix plant, conforming with specified requirements, the Contractor shall submit the accepted mix design to the Engineer for review prior to placing any shotcrete.
- D. Shotcrete shall not be placed until the submitted mix design has been approved by the Engineer in writing.

2.03 EQUIPMENT AND MIXING

- A. Equipment Standards: Equipment shall be appropriate and suitable for dry-mix or wet-mix shotcrete, as applicable, in accordance with the requirements of ACI 506.2.
- B. Batching and Mixing Equipment: Materials shall be batched by weight and machine mixed, and delivered to the site pre-mixed. For wet-mix shotcrete, conform with the applicable requirements of ASTM C94/C94M for ready-mixed concrete.

- C. **Delivery Equipment:** Conform with the applicable requirements of ACI 506.2. Equipment shall be capable of discharging mixture into delivery hose under close control and shall deliver a continuous stream of material at the proper volume to discharge nozzle. Discharge nozzle shall be equipped with a manually operated and adjustable air-injection system for directing an even distribution of air through the mixture. Nozzle shall deliver a conical discharge stream of uniform appearance. Equipment shall be cleaned daily and inspected for worn parts. Plaster guns are not permitted.
- D. **Air Supply:** System shall employ a properly operating compressor of ample capacity to perform the work. Comply with capacity requirements specified in ACI 506.2, with modification for hose lengths and working heights.

PART 3 – EXECUTION

3.01 EXAMINATION OF SUBSTRATE SURFACES

- A. Examine earth, rock, concrete, and masonry substrate surfaces, as applicable, and determine that such substrate surfaces have been properly prepared as hereinafter specified under Article 3.02.
- B. Inspect soil anchors, if required by the Contract Specifications, and determine that they are of correct size and type, and properly located and installed.
- C. Inspect reinforcing steel and determine that it is properly placed and tied, that sufficient clearances have been provided, and that it is free of grease, oil, loose rust, and other coatings that may impair bond with concrete.
- D. Assure that sleeves and other items to be embedded in shotcrete are in place and that provisions for penetrations have been made.
- E. Proceeding with shotcrete placement shall imply acceptance of substrate surfaces and conditions as satisfactory.

3.02 PREPARATION OF SUBSTRATE SURFACES

- A. Prepare earth, rock, concrete, and masonry substrate surfaces, as applicable, in accordance with ACI 506.2.
- B. Rock faces shall be free of loose rock.
- C. Absorptive substrate surfaces shall be evenly dampened before placing shotcrete.
- D. Formwork shall be designed and constructed to provide for escape of compressed air and rebound during shotcrete placement. Coordinate with Section 03 11 00, Concrete Forming.
- E. Drain any free-standing water away from shotcrete operations.

- F. Provide ground wires to establish thickness and surface planes. Install vertically and horizontally as required. Do not penetrate waterproof membranes.
- G. As an alternative to ground wires, thickness measuring pins may be used to establish layer thickness and surface plane, provided such pins do not penetrate waterproof membranes and do not detrimentally damage substrates. Install pins on 5 foot centers in each direction.

3.03 SHOTCRETE PLACEMENT

- A. Operation and Placement Standards: Shotcrete operations and placement shall conform with the applicable requirements of ACI 506.2.
- B. Gunning/Nozzle Operation:
 - 1. Build each layer by making several passes over the working area. Thickness of each layer shall be governed by the requirement that sagging of shotcrete shall not occur. Maintain top surface of thick layers at 45 degree slope. Each layer to be covered by a succeeding layer shall be allowed to take its initial set.
 - 2. Laitance, loose material, and rebound shall be removed by air-jetting. Laitance that has taken a final set shall be removed by sandblasting and the surface cleaned with air-water jet. All layers to be shot shall be damp.
 - 3. Unless otherwise permitted, begin application at the lowest elevation.
 - 4. Do not trowel or finish initial layers in any way.
- C. Rebound: Any rebound or accumulated loose aggregate shall be removed from the surface to be covered prior to placing succeeding layers. Rebound shall not be salvaged for reuse.
- D. Construction Joints: Unfinished work shall not stand more than 30 minutes unless construction joints are provided for. Construction joints shall be designed and provided as specified in Section 03 30 00, Cast-In-Place Concrete. Entire joint surface shall be cleaned, roughened, and dampened prior to application of additional shotcrete.
- E. Finishing: Bring shotcrete layers to within 1/4 inch of final finished surface. When surface has taken its initial set, trim excess material with a sharp edge cutting screed. Remove ground wires. Provide flash coat or finish coat as required for the final finish. Final finish shall be as specified in the Contract Specifications. Comply with applicable requirements of ACI 506.2.

3.04 CURING

- A. Immediately following shotcrete finishing, surfaces shall be cured for not less than seven Days using an approved curing method as specified in ACI 506.2.

3.05 CLEANING

- A. Clean surfaces and work site of rebound and waste materials, and remove from the site.

3.06 FIELD QUALITY CONTROL

- A. Requirements: Conform with applicable requirements of Section 01 45 00, Quality Control. All tests, cores, and core tests shall be performed by an independent testing laboratory or agency employed by the Contractor at no additional cost to the District.
- B. Inspections:
 - 1. Visual inspection by the Engineer will be performed of the shotcrete work, including equipment, materials, forms, reinforcement, embedded items, placement, finishing, curing, and protection of the finished product.
 - 2. Surfaces may be sounded with a hammer to locate drummy or hollow-sounding areas resulting from rebound pockets or lack of bond. Such hollow-sounding areas, voids, sags, and other defects shall be carefully cut out and replaced.
- C. Quality Control Tests:
 - 1. Test Panels:
 - a. From each 50 cubic yards of each shotcrete mix, or fraction thereof, applied in the work by each crew in each shooting position, fabricate four unreinforced test panels, each 18-inches square and 7-1/2 inches thick. Fabricate test panels in accordance with ACI 506.2. Properly cure test panels in accordance with ASTM C31/C31M and ACI 506.2.
 - b. Test panels will be visually examined by the Engineer, and shall be tested by an independent testing laboratory or agency employed by the Contractor at no additional cost to the District. Strength of shotcrete shall be considered acceptable when the average of all strength tests, as well as the average of three consecutive strength tests, representing each shotcrete mix is equal to at least 85 percent of the specified design strength and no individual strength test is less than 75 percent of the design strength. Strength tests shall be performed in accordance with ASTM C42/C42M.
 - c. The Engineer will require, at no additional expense to the District, adjustments to the mix proportions, requalification of the shotcreting crew, or additional curing of the shotcrete if either of the following conditions occur:
 - 1) The average seven-day strength of any two specimens for the shotcrete mix is less than 70 percent of the specified 28-day strength, (three days for High-Early Strength Design); or
 - 2) The average 28-day strength of any two specimens for the shotcrete mix is less than 100 percent of the specified 28-day strength.
 - 2. Test Cores:

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- a. Should the test panels indicate that shotcrete not meeting the specified requirements has been produced, the Engineer will require tests of cores, taken from the areas represented by the test panels, to determine compliance of the in-place shotcrete with the specified requirements.
- b. Test cores shall be 3 inches minimum diameters, obtained and tested in accordance with ASTM C1604/C1604M.
- c. Three cores shall be taken for each determination of in-place strength. Shotcrete in the area represented by the core tests shall be considered structurally adequate if the average of the three cores is equal to at least 85 percent of the specified design strength and no single core is less than 75 percent of the design strength. Locations represented by erratic core strengths shall be ordered to be retested at the direction of the Engineer.
- d. Fill core holes with low-slump concrete or mortar of same mix design as the placed shotcrete.

END OF SECTION 03 37 13